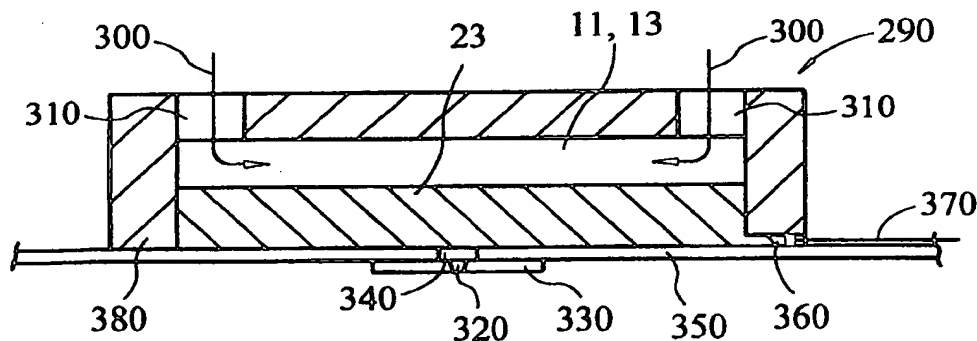




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(54) Title: DROPLET DEPOSITION APPARATUS AND METHODS OF MANUFACTURE THEREOF



(57) Abstract

A piezoelectric printhead or other droplet deposition apparatus has parallel liquid containing channels defined by a base and displaceable walls, and covered by a cover member. The channels each have at least one nozzle for ejecting droplets. Each nozzle may be disposed in the base, the cover then having two ink supply parts spaced lengthwise of each channel on opposite sides of the nozzle. Alternatively two longitudinally spaced nozzles may be provided in the base of each channel. The cover may have a conductive track connected to wall-displacing electrodes, the points of connection being outside the channels.

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Droplet Deposition Apparatus and Methods of Manufacture thereof

The present invention relates to droplet deposition apparatus, in particular an inkjet printhead, which comprise a channel communicating with a supply of droplet liquid and an opening for ejection of droplets therefrom, at least one channel side wall being displaceable in response to electrical signals, thereby to effect ejection of droplets from the channel.

Figure 1a is a cross-sectional view of the channels of the prior art inkjet printhead construction according to WO92/22429, belonging to the present applicant and incorporated herein by reference. Piezoelectric ceramic sheet 12 is poled in its thickness direction 17 and formed in one surface with channels 11 bounded on two sides lying parallel to the channel axis by channel walls 13. By means of electrodes 23 formed on either side of each wall 13, an electric field can be applied to the piezoelectric material of the walls, causing them to deflect in shear mode in a direction transverse to the channel axis. Pressure waves are thereby generated in the ink which result in the ejection of an ink droplet. These principles are known in the art, e.g. from EP-A-0 364 136, belonging to the present applicant and incorporated herein by reference.

Channels 11 are closed along one side lying parallel to the channel axis by the surface of a cover 14 having conductive tracks 16 at the same pitch interval as the ink channels formed thereon. Solder bonds 28 are formed between tracks 16 and the channel wall electrodes 23, thereby securing the cover to the base and creating an electrical connection between the electrodes and the track in a single step. To protect them from later being corroded by the ink, electrodes and tracks are then given a passivant coating.

As shown in figure 1b, which is a sectional view taken along the longitudinal axis A of a single channel of the prior art printhead of figure 1a, a nozzle plate 20 having respective ink ejection nozzles 22 is mounted at the front of the sheet 12 whilst an ink manifold 26 is defined at the rear by a manifold structure 21. Tracks 16 are led

to the rear of cover 14 for connection to a drive circuit, typically embodied in a microchip 27 which in turn is driven by signal received via input tracks 18.

In printheads of this ilk, the channel walls – and in particular the electrodes formed thereon – are often passivated so as to protect from subsequent corrosion by the ink. Reference is made in this regard to WO95/07820, incorporated herein by reference.

In the device discussed above, however, such conventional passivation prior to attachment of the cover would inhibit the formation of solder bonds between the electrodes and the tracks. On the other hand, passivation after the cover has been attached can only be applied from the end of the channel, resulting in low quality coating of the electrodes and tracks, especially at the midpoint of the channel remote from the channel ends.

The present invention has as an objective a printhead construction that retains the connection advantages associated with the conductive tracks formed on the cover of the prior art construction and yet is amenable to passivation.

Accordingly, the present invention consists in one aspect in droplet deposition apparatus comprising at least one channel having means for communicating with a supply of droplet liquid and an opening for ejection of droplets;

the channel being bounded on at least one side lying parallel to the channel axis by a channel wall associated with actuator means; the actuator means effecting displacement of the channel wall in response to electrical signals, thereby to effect ejection of droplets from the channel;

the channel being bounded on a further side lying parallel to the channel axis by a cover surface, the cover surface having formed thereon at least one conductive track for conveying electrical signals to said actuator means, the point of electrical connection between the track and the actuator means lying outside the channel.

Since the sole point of electrical connection between the track and the actuator in accordance with the present invention lies outside of the channel and thus out of contact with the ink (with its potentially corrosive effects), passivation of this point is no longer required. The channel itself can therefore be conventionally passivated via the

open tops of the channels. Thereafter, the cover can be attached and electrical contact established between the conductive tracks on the cover and the actuator means associated with the channel walls. Even in a printhead that – because of the type of ink it is designed to fire – does not require passivation, a point of electrical connection lying outside the channel as per the present invention is less likely to fail in fatigue than the channel-length solder bonds of the prior art device of figures 1a,1b.

A corresponding method according to a first aspect of the invention consists in a method of manufacture of droplet deposition apparatus method of manufacture of droplet deposition apparatus, the method comprising the steps of:

forming in a base component at least one open-topped channel and, bounding said channel on at least one side lying parallel to the channel axis, a channel wall associated with actuator means for effecting displacement of the channel wall in response to electrical signals, thereby to effect ejection of droplets from the channel;

closing the channel on a further side lying parallel to the channel axis by a cover surface, the cover surface having formed thereon at least one conductive track for conveying electrical signals to said actuator means; and

electrically connecting the conductive track and the actuator means at a point lying outside the channel.

Advantageously, the step of closing the channel results in the electrical connection of the conductive track and the actuator means, thereby simplifying the manufacturing process.

The first aspect of the invention also consists in droplet deposition apparatus comprising: a bottom sheet of piezo-material poled droplet deposition apparatus comprising:

a bottom sheet of piezo-material poled in a direction normal to said sheet and formed with a multiplicity of parallel, open-topped channels mutually spaced in an array direction normal to the length of the channels and defined each by facing side walls and a bottom surface extending between said side walls;

a top sheet facing said bottom surfaces of said channels and bonded to said side walls to close said channels at the tops thereof;

respective nozzles communicating with said channels for the ejection of droplets of liquid therefrom;

connection means for connecting said channels with a source of droplet deposition liquid;

wherein each channel is formed with a forward part in which electrodes are provided on opposite sides of at least one of the side walls defining the channel, thereby to form a shear mode actuator for effecting droplet expulsion from the channel; and

wherein each channel is formed with a rearward part having an electrically-conductive coating which is in electrical contact with the at least one electrode on the channel-facing sides of the side walls in the forward part;

sealing means separating the forward part from the rearward part; and wherein the apparatus further comprises conductive tracks formed on that surface of said top sheet that is bonded to said side walls, the conductive tracks being in electrical contact with the electrically-conductive coating in said rearward part.

A corresponding method comprises the steps of forming a bottom sheet with a layer of piezo-material poled in a direction method of manufacture of a droplet deposition apparatus comprising the steps of:

forming a bottom sheet with a layer of piezo-material poled in a direction normal to said sheet;

forming a multiplicity of parallel, open-topped channels mutually spaced in an array direction normal to the length of the channels, each channel being defined by facing side walls and a bottom surface extending between said side walls, each channel further having a forward part and a rearward part;

forming electrodes on opposite sides of at least one of the side walls defining the forward part of each channel, thereby to form a shear mode actuator for effecting droplet expulsion from the channel; and

forming in the rearward part of each channel an electrically-conductive coating in electrical contact with a respective electrode;

providing a top sheet having a surface formed with conductive tracks thereon;

and

bonding that surface of the top sheet having conductive tracks thereon to said side walls so as to close said channels at the tops thereof;

establishing electrical contact between said tracks and the respective electrically-conductive coating of each channel; and

providing sealing means separating the forward and rearward parts of each channel.

A second aspect of the present invention consists in droplet deposition apparatus comprising droplet deposition apparatus comprising:

at least one longitudinal, open-topped droplet liquid channel defined by facing longitudinal side walls and a bottom, longitudinal surface extending between the side walls;

means for applying an electric field to piezoelectric material in at least one of said walls, thereby to effect displacement of the wall relative to said longitudinal channel so as to eject a droplet from the channel; and

a cover closing the open, longitudinal top side of the channel;

wherein said bottom longitudinal surface of the channel is formed with an opening for droplet ejection, and;

the cover incorporates two ports for supply of droplet liquid, the ports being spaced along the channel on either side of the opening.

Such a construction again simplifies the manufacture of known printheads, particularly those of the "top shooter" kind discussed in WO91/17051 (belonging to the applicant and incorporated herein by reference). Figure 2 shows a sectional view along the channels of such a prior art printhead, with those features that correspond to figure 1 being denoted by corresponding reference numbers. Droplet ejection takes place from a nozzle 22 formed in the channel cover component 60 whilst droplet liquid is supplied to the channel via ports 33 formed in the channel base and which are typically connected in their turn to ink supply conduits (not shown) formed in a base component 35 that is separate from the piezoelectric channelled component 12.

In accordance with the invention, an opening communicating with a droplet

ejection orifice is formed in the bottom surface of the channel, thereby allowing the cover component to incorporate ports for supply of ink into the channel. A further, separate base component is consequently no longer required.

A third aspect of the invention comprises droplet deposition apparatus comprising:

at least one longitudinal, open-topped droplet liquid channel defined by facing longitudinal side walls and a bottom, longitudinal surface extending between the side walls;

means for supplying droplet liquid to the channel;

means for applying an electric field to piezoelectric material in at least one of said walls, thereby to effect displacement of the wall relative to said longitudinal channel so as to eject a droplet from the channel; and

a cover closing the open, longitudinal top side of the channel;

wherein the bottom longitudinal surface of the channel is formed with two openings for droplet ejection, the openings being spaced along the channel.

Such a construction brings to the arrangement of PCT application no. PCT/GB98/01495 – belonging to the present applicant and incorporated herein by reference – the aforementioned advantage of reduced component count.

Corresponding method claims are also comprised in the present invention, and other aspects are as set out in other independent claims.

Further advantageous embodiments of the invention are set out in the description, drawings and dependent claims.

The disclosure of all claims is deemed incorporated here as consistory clauses, unless already set out above.

The invention will now be described by way of example by reference to the following diagrams, of which:

Figure 3 is a sectional view taken along the channel axis of a printhead according to a first embodiment of a first aspect of the present invention;

Figures 4a and 4b show detail of the rear part of the printhead of figure 3 before and after attachment of the cover respectively;

Figure 5 is a sectional view taken along the channel axis of a printhead according to a second embodiment of a first aspect of the present invention;

Figure 6 is a sectional view taken along the channel axis of a printhead incorporating both first and second aspects of the present invention;

Figure 7 is a sectional view taken along the channel axis of a printhead according to a second embodiment of a second aspect of the present invention;

Figure 8 is a detail perspective view of the end of the piezoelectric body of the printhead of figure 7.

Figures 9 and 10 are sectional and detail sectional views respectively of an alternative embodiment of the printhead shown in figure 7.

Figure 3 illustrates a printhead according to a first embodiment of the first aspect of the present invention, with those features that are common to figure 3 and the prior art printhead of figures 1 and 2 being designated by common reference numerals.

As in the prior art device, a piezoelectric ceramic body 12 poled in the thickness direction is formed with channels 11 separated by channel walls 13. As known from EP-A-0 364 136 referred to above, electrodes 23 are formed along each wall 13 in the ink-containing channel 11 as well as extending along a rearward groove 100 to the rear face 130 of the body. In addition, there is provided a cover 14, a surface 15 of which closes the open side of each of the channels 11, a nozzle plate 20 with nozzles 22 for droplet ejection and a manifold for supply of ink into the channel in the form of a transverse cut in the body 12. Surface 15 of cover 14 has tracks 16 formed thereon (suitable processes are well known) which in turn are connected to microchip 27 (which is illustrated figuratively in figure 3 and not to scale) which in turn receives input signals from input tracks 18.

Detail of the rear part of the printhead prior to attachment of the cover is shown in figure 4a: a passivation layer 140 (not shown in figure 3 but indicated by dashed hatching in figure 4a) is applied over the entirety of the electrodes 23 (indicated by solid hatching in both figures 3 and 4a) in the channel and part way along the rearward groove 100. In contrast to the prior art construction, passivation is carried out

before attachment of the cover and advantageously according to the method described in WO95/07820, belonging to the present applicant and incorporated herein by reference.

A mechanical bond between body and surface 15 of cover 14 is achieved by means of adhesive layer 160, applied to the end surfaces of the walls 13 in the region of the channels 11 prior to assembly of cover and body and preferably in accordance with the method discussed in WO95/04658, belonging to the present applicant and incorporated herein by reference. Figure 4b illustrates the assembled printhead, with the adhesive bond being indicated at 220. Such a bond may indeed be tougher and have a longer fatigue life than the corresponding solder bond of the prior art construction described above.

Electrical connection between the conductive tracks 16 on the cover and that part of the electrode 23 in the rearward groove 100 is achieved by a protrusion 170 of a malleable, deformable, conductive material such as solder affixed to the end 180 of track 16. On assembly of the cover to the body, as illustrated in figure 4b, protrusion 170 comes into contact with electrode 23 and is deformed, thereby providing an effective electrical contact 200 between electrode 23 and track 16.

A bead 190 of a sealing paste or high viscosity glue is also applied so as to form on assembly an ink seal 210 between the end of the ink channel 11 and the electrical contact 200. Such a seal protects the electrical contact from later corrosion by ink. Preferably, the seal is positioned so as to straddle the free end 150 of the passivation layer 140, thereby preventing the seepage of ink under the passivation layer from where it might otherwise attack the electrode material 23.

Figure 5 illustrates a second embodiment of the first aspect of the present invention. A ceramic piezoelectric body 290 is, as in the previous embodiment, poled in the thickness direction and formed with channels 11 separated by channel walls 13 which in turn have an electrode 23 formed on each side. Ink ejection, however, takes place from a centrally located nozzle 320 formed either directly in the cover 350 or, as shown, in a nozzle plate 330 communicating with the channel via an aperture 340 formed in the cover. Body 290 is additionally formed with two manifolds 310 for supply

of from both ends of the channel, as indicated by arrows 300. A further structure (not shown) will supply the manifolds with ink from a reservoir.

Such a "double-ended" printhead configuration is disclosed in WO91/17051, belonging to the present applicant and incorporated herein by reference, and has advantages in terms of a lower operating voltage over the "single-ended" configuration described above. Furthermore, the configuration of base 290 is suited to manufacture by moulding – a technique that is potentially more attractive from the point of view of manufacturability than conventional sawing techniques described in the aforementioned EP-A-0 364 136.

The connection of the channel electrode 23 to conductive tracks 370 formed on that surface of cover 350 facing body 290 is as already described with regard to figures 3, 4a and 4b, however, and is located in groove 360 formed at one side of the body 290. Similarly, in the region of the channel itself (the channel walls of which are passivated prior to assembly) and at that end 380 of the body not occupied by an electrical connection, cover 350 is attached to the piezoelectric ceramic body by a conventional adhesive bond (not shown).

In order to minimise the distance travelled by the ink from the channel proper 11 to the outlet of the nozzle 320 – thereby reducing pressure losses and consequent reductions in droplet ejection velocity – the nozzle 320 may be formed in the cover 350 itself. Advantageously the nozzle is formed by laser ablation as described, for example, in WO93/15911 incorporated herein by reference, and to this end the cover may be made of an easily ablatable material, suitably a polymer such as polyimide, polycarbonate, polyester or polyetheretherketone, typically of 50 μ m thickness.

The stiffness of a cover plate formed of such an easily ablatable material may be increased by application of a coating of stiffer material to the inner and outer surfaces of the ablatable cover plate. Particularly suitable for this purpose is silicon nitride: it can also be used as a passivant coating in the process of the aforementioned WO95/07820, is deposited as a smooth coating suitable for the subsequent application of a non-wetting coating, and will not short out electrodes of adjacent channels due to its non-conducting properties. Two layers of such a material

placed either side of the polyimide cover and each having a thickness of around 5% of that of the cover ($2.5\mu\text{m}$ in the case of a $50\mu\text{m}$ thick cover) will typically increase bending stiffness by a factor of 5–10 (based on standard compound beam theory and assuming a value of Young's Modulus for the stiffening material approximately 100 times greater than that of the polymer and good adhesion between the stiff and polymer materials). Such a thin layer has no significant effect on the ease with which the cover plate can be ablated to form a nozzle, particularly if the material of the layer itself is to some degree ablatable.

Expressed in broad terms, the cover plate for an inkjet printer comprises a layer of a first, easily ablatable, material having further layers bonded on opposite sides thereof, the further layers each being of a material having a stiffness at least an order of magnitude greater than that of the first material and being of a thickness at least an order of magnitude less than that of the first layer.

Referring now to figure 6, there is shown a printhead incorporating both first and second aspects of the present invention. Piezoelectric ceramic body 400 is formed with channels 11, channel-separating walls 13 and electrodes 23 which are supplied with actuating signals via conductive tracks 410 connected to drive circuitry (not shown). Unlike previous embodiments, however, droplet ejection takes place from a nozzle 420 communicating with an opening 430 formed in the body 400 at the closed, bottom surface 440 of the channel 11 – this is in contrast to figure 5 where the nozzle 320 is located in a cover 350 closing the open, top side of the channel 11.

Moulding is again the preferred method of manufacture of the channelled body 400, and the arrangement of figures 4a and 4b is again employed for electrical connection between the electrodes 23 and conductive tracks 410. Communication hole 430 may also be formed during the moulding process or may be formed subsequently, e.g. by means of a laser. Cover 450 no longer incorporates a nozzle but is instead formed with ink inlet ports 460. Such an arrangement has a lower component count than embodiments discussed earlier and has consequential manufacturing advantages. Alternatively, ink supply ports could be formed in the channelled component, e.g. at the channel ends.

The printhead of figure 7 also employs a cover component 500 having ink inlet ports 520, 522 and 524 located at either end and in the middle of a channel 11 formed in a piezoelectric body 530. Channel walls are separated by a gap 540 into two sections 550,560 supplied by ports 520,522 and 522,524 respectively, with each section being independently actuable by means of respective electrodes 570, 580 driven by drive circuits (not shown) via conductive tracks 650,660. For each section there is provided a respective nozzle 610,620 formed in a nozzle plate 615 and communicating with a section of the channel 11 via communication holes 630,640 formed in the bottom surface of the channel at points located midway between the respective inlet ports for that section.

Such a configuration is described in co-pending UK patent application no. 9710530.8, belonging to the applicant and incorporated herein by reference, and results in a printhead having two parallel rows of independently actuable printing elements that is compact and which has a reduced actuating voltage per unit droplet ejection velocity due to the "double-ended" ink supply to each channel section.

Unlike earlier embodiments, the conductive tracks 650,660 that electrically connect the channel electrodes to the drive chips are formed on the piezoelectric body itself, advantageously in the same step in which the electrodes 570,580 are deposited on the channel walls. Such an arrangement is known from EP-A-0 397 441, belonging to the applicant and incorporated herein by reference, and consequently will not be described in further detail here. Connection between track 650,660 and drive chip 590,600 may be achieved by any conventional method, including wire bonding or gold ball connection.

Piezoelectric body 530 may be moulded: in addition to having clear manufacturing advantages, such a process permits the end of the channel 11 to be formed as illustrated in figure 8, namely with a smooth, continuous transition 700 from the top surface 720 of the body to both the channel wall 730 and the bottom, longitudinal surface 710 of the channel. This in turn avoids discontinuities in the subsequently-deposited electrode material and the associated heating effects which might have a deleterious effect on the operational life of the printhead as a whole.

Alternatively, channels may be formed in the piezoelectric component by sawing using a disc cutter – as described e.g. in EP-A-0 309 148 – and illustrated in the sectional and detail sectional views of figures 9 and 10. It follows that the depth of the channel 11 will run out more gradually at each end, as shown at 800, and that the piezoelectric channel wall defined between adjacent sawn channels 11 will run continuously between the two active sections 550,560. However, a break 810 in the electrodes on the channel walls at a location between the two sections ensures that each the wall in active section can be actuated independently by signals supplied via electrical input 820. Such a break may be achieved e.g. by masking during deposition of the metal plating or by removal of the plating by a laser.

Connection between the electrodes on the channel walls and the electrical input 820, whilst not shown in detail, may be achieved by any of the known techniques including wire bond between tracks formed in shallow "run-out" grooves formed in the area 900 rearward of the channel 11 (described in the aforementioned EP-A-0 364 136) or conductive adhesive (e.g. anisotropic conductive adhesive) between conductive tracks formed in area 900 on the surface of the piezoelectric sheet itself and (described in EP-A-0 397 441).

As in the embodiment of figure 7, each channel 11 is closed along its two active sections 550,560 by appropriate lengths 820,830 of a cover component 500 which is also formed with ports 520,522,540 that allow ink to be supplied to each channel active section and, optionally, allow ink to be circulated through each channel section for cleaning purposes, as is generally known. Ports may be positioned so as to define the edge of an active section, as in the case of port 522, in which case manufacture is simplified. In the example shown, the width of cover port 552 and the cover closing lengths 820, 803 are of the same order of magnitude, typically 2mm.

Ink ejection from each active section is again via openings that communicate the channel with the opposite surface of the piezoelectric component (sheet 860) to that in which the channel is formed. In the present embodiment, these openings take the form of slots 840,850 which extend some distance – typically 200 μ m – in the longitudinal direction of the channel so as to allow some leeway in the placing of the

respective nozzles 870,880 in nozzle plate 890. Offsetting of nozzles is generally necessary whenever simultaneous droplet ejection from adjacent channels is not possible e.g. in "shared wall" printheads of the kind illustrated, is generally known e.g. from EP-A-0 376, and will not therefore be discussed in any greater detail.

Printheads according to the present invention may also be made in a modular format as described in the aforementioned WO91/17051, each module being formed in opposite end surfaces thereof with respective channel parts so that, upon butting together of modules, further channels are formed between respective pairs of butted modules. In such arrangements, the respective channel parts may include at least part of a slot formed in the channel base and of sufficient length that, even if a pair of butted modules and their respective slot parts are not perfectly aligned, there remains an overlap between the two slot halves sufficient to accommodate a nozzle.

As in the previous embodiment, nozzles 870,880 are formed in a nozzle plate 890 which, as illustrated, may extend over the substantially the entire length of piezoelectric sheet 860 so as to provide a suitably large area for engagement e.g. of a capping and/or wiping mechanism.

It should be understood that this invention has been described by way of examples only and that a wide variety of modifications can be made without departing from the scope of the invention. Features shown in the context of the first aspect of the invention may be equally applicable to the second aspect and vice versa.

The piezoelectric channel walls, for example, can be polarised in opposite directions normal to the plane of the channel axes as known, for example, from EP-A-0 277 703 incorporated herein by reference. Alternatively, polarisation of the channel walls can be parallel to the plane of the channel axes with electrodes formed in the channel walls themselves as known, for example, from EP-A-0 528 647.

Nor is every channel in a printhead required to be capable of droplet ejection: active channels capable of droplet ejection may be alternated in the printhead with inactive – so-called "dummy" channels – as described, for example, in the aforementioned EP-A-0 277 703.

CLAIMS

1. Droplet deposition apparatus comprising:
 - at least one longitudinal, open-topped droplet liquid channel defined by facing longitudinal side walls and a bottom, longitudinal surface extending between the side walls;
 - means for applying an electric field to piezoelectric material in at least one of said walls, thereby to effect displacement of the wall relative to said longitudinal channel so as to eject a droplet from the channel; and
 - a cover closing the open, longitudinal top side of the channel;
 - wherein said bottom longitudinal surface of the channel is formed with an opening for droplet ejection, and;
 - the cover incorporates two ports for supply of droplet liquid, the ports being spaced along the channel on either side of the opening.
2. Apparatus according to 1, wherein the supply ports are spaced on either side of the opening by an equal amount.
3. Apparatus according to claim 1 or 2, wherein the bottom longitudinal surface of the channel is formed with at least two openings, the openings being spaced along the channel.
4. Apparatus according to claim 3, wherein the cover incorporates droplet supply ports spaced along the channel so as to lie either side of each opening.
5. Apparatus according to any preceding claim, wherein the piezoelectric material deforms in shear mode when subject to the electric field.
6. Apparatus according to any preceding claim, wherein an electrode is formed on a channel-facing surface of the channel wall.

7. Apparatus according to claim 6, wherein an electrode is also formed on the channel wall on a surface opposed to the channel-facing surface of the channel wall.
8. Apparatus according to any preceding claim, wherein said channel wall is displaceable in response to electrical signals in a direction transverse to the axes of the channels.
9. Apparatus according to any preceding claim, wherein said bottom, longitudinal surface is defined by a base, said base and said longitudinal side walls being integral.
10. Apparatus according to any preceding claim and including a plurality of longitudinal channels arranged parallel to one another.
11. Droplet deposition apparatus comprising:
 - at least one longitudinal, open-topped droplet liquid channel defined by facing longitudinal side walls and a bottom, longitudinal surface extending between the side walls;
 - means for supplying droplet liquid to the channel;
 - means for applying an electric field to piezoelectric material in at least one of said walls, thereby to effect displacement of the wall relative to said longitudinal channel so as to eject a droplet from the channel; and
 - a cover closing the open, longitudinal top side of the channel;
 - wherein the bottom longitudinal surface of the channel is formed with two openings for droplet ejection, the openings being spaced along the channel.
12. Apparatus according to claim 11, wherein the means for supplying droplet liquid comprises supply ports in the cover, spaced along the channel so as to lie either side of each opening.
13. Apparatus according to claim 11 or claim 12, wherein the piezoelectric material

deforms in shear mode when subject to the electric field.

14. Apparatus according to any of claims 11 to 13, wherein an electrode is formed on a channel-facing surface of the channel wall.

15. Apparatus according to claim 14, wherein an electrode is also formed on the channel wall on a surface opposed to the channel-facing surface of the channel wall.

16. Apparatus according to any of claims 11 to 15, wherein said channel wall is displaceable in response to electrical signals in a direction transverse to the axes of the channels.

17. Apparatus according to any of claims 11 to 16, wherein said bottom, longitudinal surface is defined by a base, said base and said longitudinal side walls being integral.

18. Apparatus according to any of claims 11 to 16 and including a plurality of longitudinal channels arranged parallel to one another.

19. Method of manufacture of droplet deposition apparatus comprising the steps of:
providing a body including piezoelectric material and having at least one longitudinal, open-topped channel, the channel being defined by facing longitudinal side walls and a bottom, longitudinal surface extending between the side walls;
forming an opening in the bottom longitudinal surface of the channel for ejection of droplet liquid;

providing means for applying an electric field to piezoelectric material in at least one of said walls, thereby to effect displacement of the wall relative to said longitudinal channel so as to eject a droplet from the channel;

closing the open, longitudinal top side of the channel by means of a cover having two droplet fluid supply ports arranged so as to lie spaced along the channel

on either side of the opening.

20. Method according to claim 19 comprising the step of forming said bottom, longitudinal surface and said longitudinal side walls so as to be integral with one another.

21. Method according to claim 20 comprising the steps of providing a body of piezoelectric material and removing material from said body, thereby to form said channel in said body.

22. Method according to claim 21 comprising the steps of
providing a body in the form of a sheet having first and second opposite surface;

removing material from the first surface of said body, thereby to form the channel;

forming an opening in the bottom longitudinal surface of the channel, the opening communicating with said second surface of the sheet.

23. Method according to claim 24 comprising the step of polarising the piezoelectric material of the sheet in a direction perpendicular to said first and second surfaces.

24. Method of manufacture of droplet deposition apparatus comprising the steps of:
providing a body including piezoelectric material and having at least one longitudinal, open-topped droplet liquid channel, the channel being defined by facing longitudinal side walls and a bottom, longitudinal surface extending between the side walls;

forming in the bottom longitudinal surface of the channel two openings for ejection of droplet liquid, the openings being spaced along the channel;

providing means for applying an electric field to piezoelectric material in at least one of said walls, thereby to effect displacement of the wall relative to said longitudinal

channel so as to eject a droplet from the channel;
closing the open, longitudinal top side of the channel by means of a cover.

25. Method according to claim 24 comprising the step of closing the open longitudinal top side of the channel by means of a cover incorporating droplet supply ports spaced along the channel so as to lie either side of each opening.

26. Method according to claims 24 or 25 comprising the step of forming said bottom, longitudinal surface and said longitudinal side walls so as to be integral with one another.

27. Method according to claim 26 comprising the steps of providing a body of piezoelectric material and removing material from said body, thereby to form said channel in said body.

28. Method according to claim 24 comprising the steps of
providing a body in the form of a sheet having first and second opposite surface;
removing material from the first surface of said body, thereby to form the channel;
forming said two openings in the bottom longitudinal surface of the channel, the openings communicating with said second surface of the sheet.

29. Method according to claim 28 comprising the step of polarising the piezoelectric material of the sheet in a direction perpendicular to said first and second surfaces.

30. Droplet deposition apparatus comprising at least one channel having means for communicating with a supply of droplet liquid and an opening for ejection of droplets;
the channel being bounded on at least one side lying parallel to the channel axis by a channel wall associated with actuator means; the actuator means effecting

displacement of the channel wall in response to electrical signals, thereby to effect ejection of droplets from the channel;

the channel being bounded on a further side lying parallel to the channel axis by a cover surface, the cover surface having formed thereon at least one conductive track for conveying electrical signals to said actuator means, the point of electrical connection between the track and the actuator means lying outside the channel.

31. Method of manufacture of droplet deposition apparatus, the method comprising the steps of:

forming in a base component at least one open-topped channel and, bounding said channel on at least one side lying parallel to the channel axis, a channel wall associated with actuator means for effecting displacement of the channel wall in response to electrical signals, thereby to effect ejection of droplets from the channel;

closing the channel on a further side lying parallel to the channel axis by a cover surface, the cover surface having formed thereon at least one conductive track for conveying electrical signals to said actuator means; and

electrically connecting the conductive track and the actuator means at a point lying outside the channel.

32. Method according to claim 31 and wherein said step of closing the channel electrically connects said conductive track and actuator means.

33. Apparatus or method according to any of claims 30, 31 or 32, wherein the point of electrical connection is sealed from ingress of droplet fluid from the channel.

34. Apparatus or method according to any of claims 30 to 33, wherein an area adjacent said channel has an electrically-conductive coating which is in electrical contact with the actuator means associated with at least one channel wall of said channel, the conductive track being in electrical contact with said electrically-conductive coating.

35. Apparatus or method according to claim 34, wherein said area is a groove.
36. Apparatus or method according to claim 35, wherein the groove is of lesser depth than the channel.
37. Apparatus or method according to claim 35 or 36, wherein the groove is co-linear with the channel.
38. Apparatus or method according to any of claims 31 to 33, wherein the groove is sealed by sealing means against ingress of droplet fluid from the channel.
39. Apparatus or method according to any of claims 30 to 34, wherein the electrical contact is made by a deformable conductive material interposed between the electrically-conductive coating and the conductive track.
40. Apparatus or method according to claim 39, wherein the deformable conductive material is solder.
41. Apparatus or method according to any of claims 30 to 40, wherein a protective coating is applied to the channel wall.
42. Apparatus or method according to claim 41 and wherein said electrically-conductive coating further extends over at least a channel-facing surface of the channel wall, the protective coating being applied to said electrically-conductive coating.
43. Apparatus or method according to claim 41 when dependent from claim 34, wherein the protective coating terminates in said area adjacent said channel.
44. Method of manufacture according to claim 31 or any claim dependent

therefrom, wherein a protective coating is applied to at least one of the channel walls prior to closing the channel by the cover.

45. Method according to claim 44 when dependent on claim 43 and comprising the further step of masking the point at which the conductive track and the actuator means are electrically connected prior to applying the protective coating to at least one of the channel walls.

46. Apparatus or method according to claim 38, wherein said sealing means extends over the termination of the protective coating in said area adjacent said channel.

47. Apparatus or method according to any of claims 30 to 46, wherein the tops of said channel walls are attached to the cover surface by a non-conducting bond.

48. Apparatus or method according to claim 47, wherein the non-conductive bond is an adhesive bond.

49. Apparatus or method according to any of claims 30 to 48, wherein a plurality of channels are formed in an array, the channels lying parallel to one another and defining channel walls therebetween.

50. Apparatus or method according to claim 49, wherein said channel walls are displaceable in response to electrical signals in a direction transverse to the axes of the channels and parallel to the channel array direction.

51. Apparatus or method according to any of claims 30 to 40, wherein the channel wall comprises piezoelectric material to which said electrical signals are applied.

52. Apparatus or method according to claim 51, wherein said piezoelectric material

deforms in shear mode when subject to said electrical signals.

53. Apparatus or method according to claim 52, wherein an electrode is formed on a channel-facing surface of the channel wall and the piezoelectric material is polarised in a direction perpendicular both to the array direction and to the channel axis.

54. Apparatus or method according to any of claims 30 to 53, wherein the body comprises a sheet of piezoelectric material, the plurality of channels being formed in one surface of the sheet.

55. Apparatus or method according to claim 54, wherein the piezoelectric material is polarised in a direction normal to the surface of the sheet.

56. Apparatus or method according to any of claims 30 to 55, wherein said cover is formed with ports for supply of droplet liquid into said channel.

57. Droplet deposition apparatus comprising:

- a bottom sheet of piezo-material poled in a direction normal to said sheet and formed with a multiplicity of parallel, open-topped channels mutually spaced in an array direction normal to the length of the channels and defined each by facing side walls and a bottom surface extending between said side walls;

- a top sheet facing said bottom surfaces of said channels and bonded to said side walls to close said channels at the tops thereof;

- respective nozzles communicating with said channels for the ejection of droplets of liquid therefrom;

- connection means for connecting said channels with a source of droplet deposition liquid;

- wherein each channel is formed with a forward part in which electrodes are provided on opposite sides of at least one of the side walls defining the channel, thereby to form a shear mode actuator for effecting droplet expulsion from the

channel; and

wherein each channel is formed with a rearward part having an electrically-conductive coating which is in electrical contact with the at least one electrode on the channel-facing sides of the side walls in the forward part;

sealing means separating the forward part from the rearward part; and wherein the apparatus further comprises conductive tracks formed on that surface of said top sheet that is bonded to said side walls, the conductive tracks being in electrical contact with the electrically-conductive coating in said rearward part.

58. Method of manufacture of a droplet deposition apparatus comprising the steps of:

forming a bottom sheet with a layer of piezo-material poled in a direction normal to said sheet;

forming a multiplicity of parallel, open-topped channels mutually spaced in an array direction normal to the length of the channels, each channel being defined by facing side walls and a bottom surface extending between said side walls, each channel further having a forward part and a rearward part;

forming electrodes on opposite sides of at least one of the side walls defining the forward part of each channel, thereby to form a shear mode actuator for effecting droplet expulsion from the channel; and

forming in the rearward part of each channel an electrically-conductive coating in electrical contact with a respective electrode;

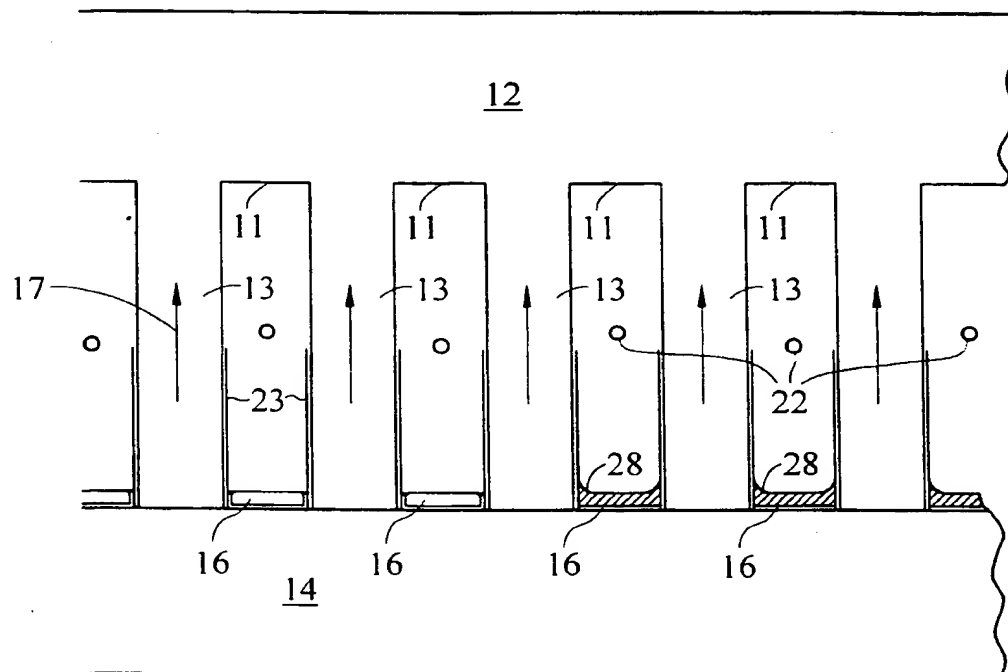
providing a top sheet having a surface formed with conductive tracks thereon; and

bonding that surface of the top sheet having conductive tracks thereon to said side walls so as to close said channels at the tops thereof;

establishing electrical contact between said tracks and the respective electrically-conductive coating of each channel; and

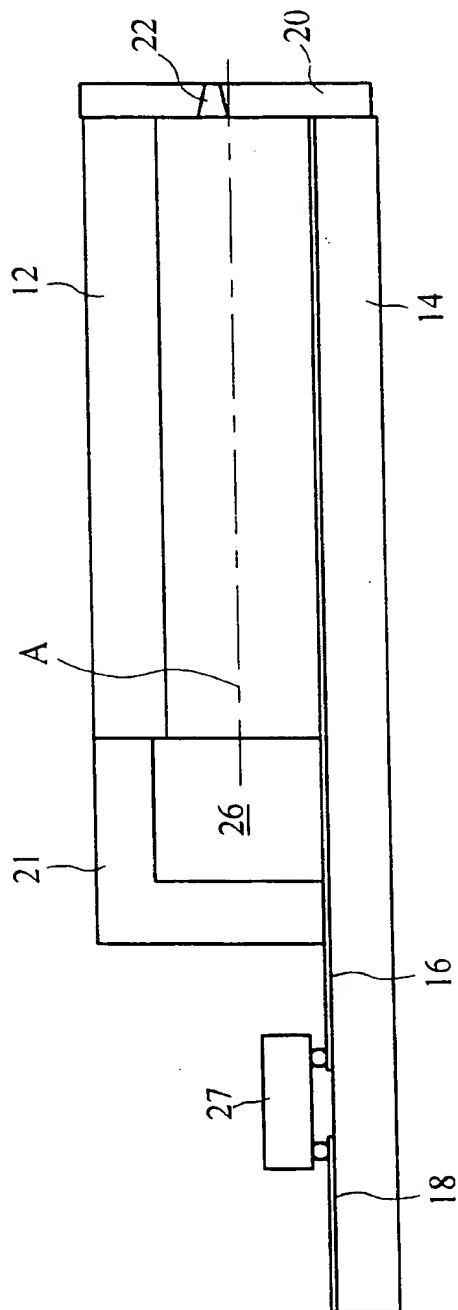
providing sealing means separating the forward and rearward parts of each channel.

1/10

Fig. 1A PRIOR ART

2/10

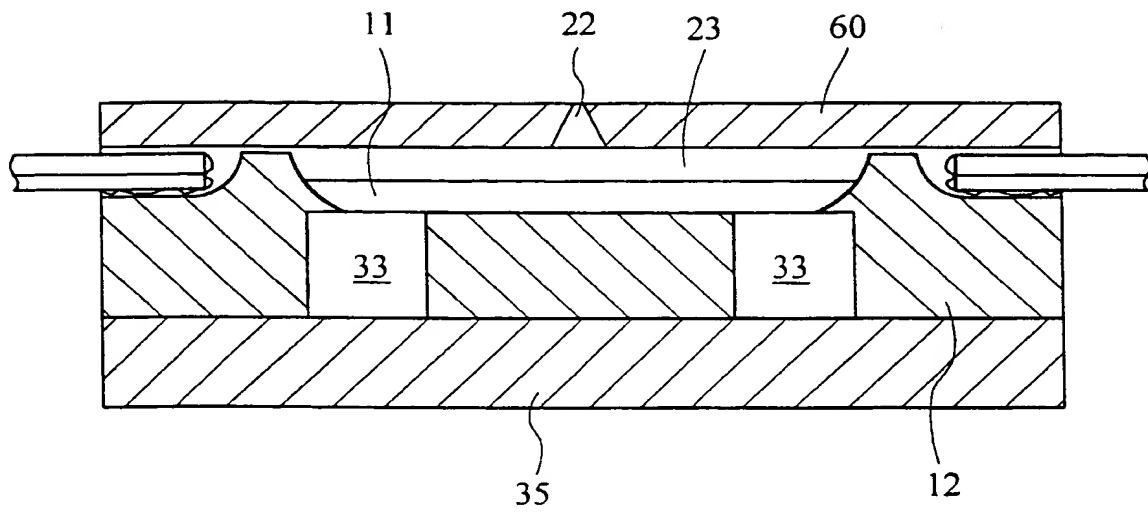
Fig. 1B PRIOR ART



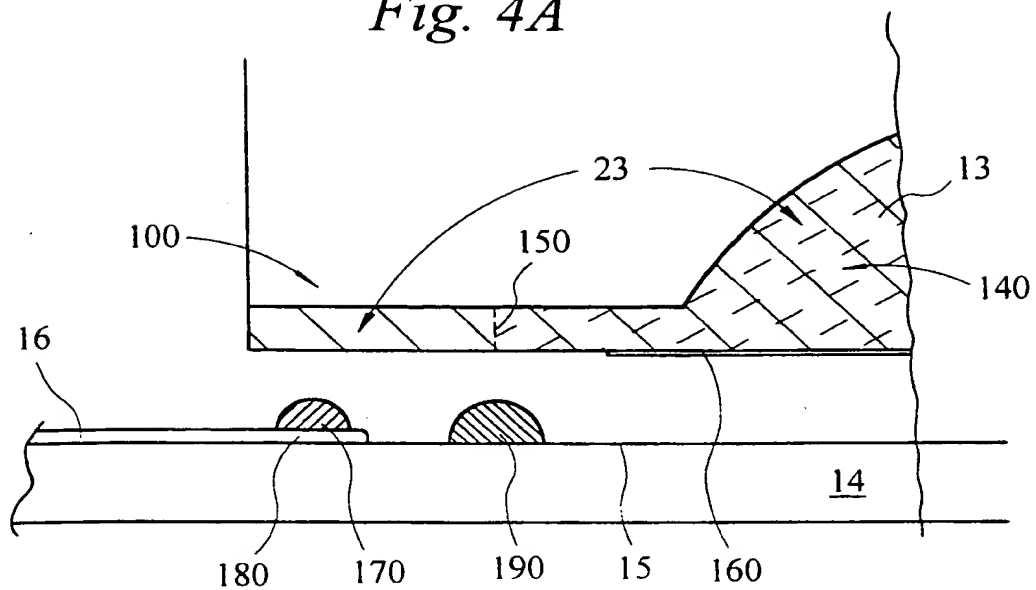
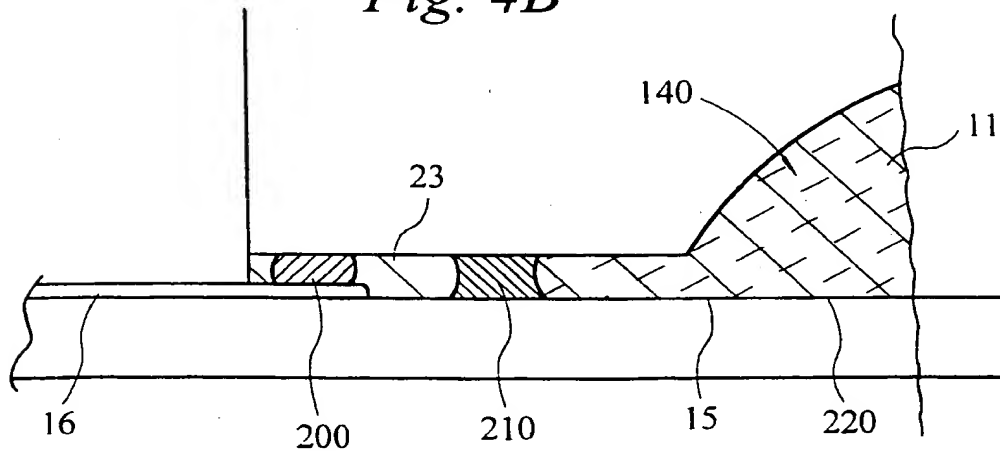
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Fig. 2

PRIOR ART



5/10

Fig. 4A*Fig. 4B*

6/10

Fig. 5

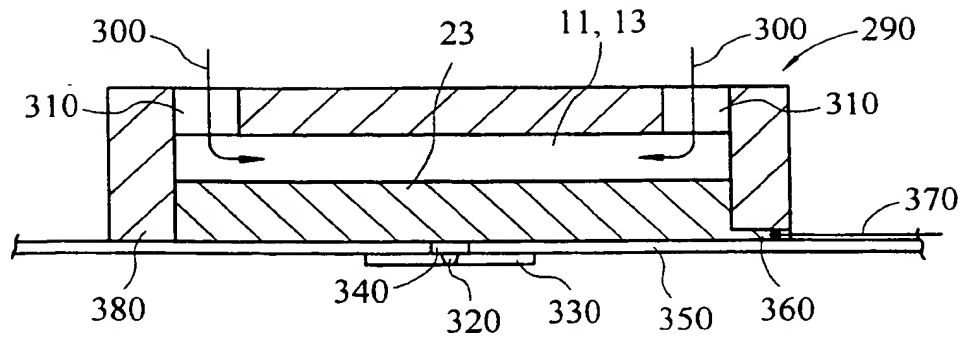
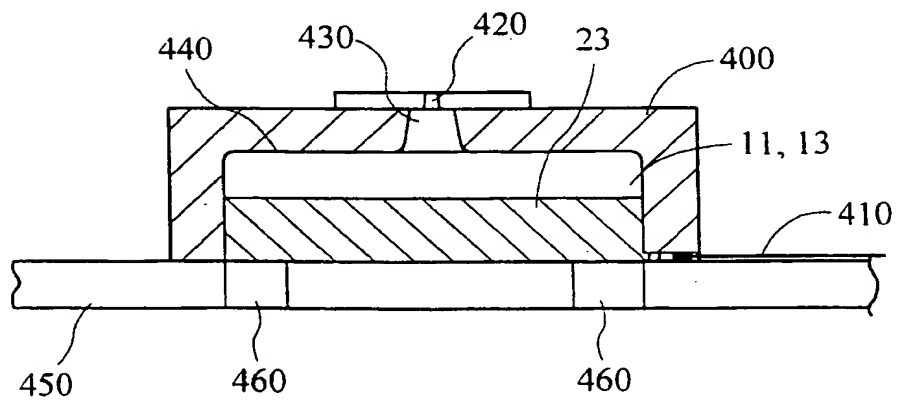
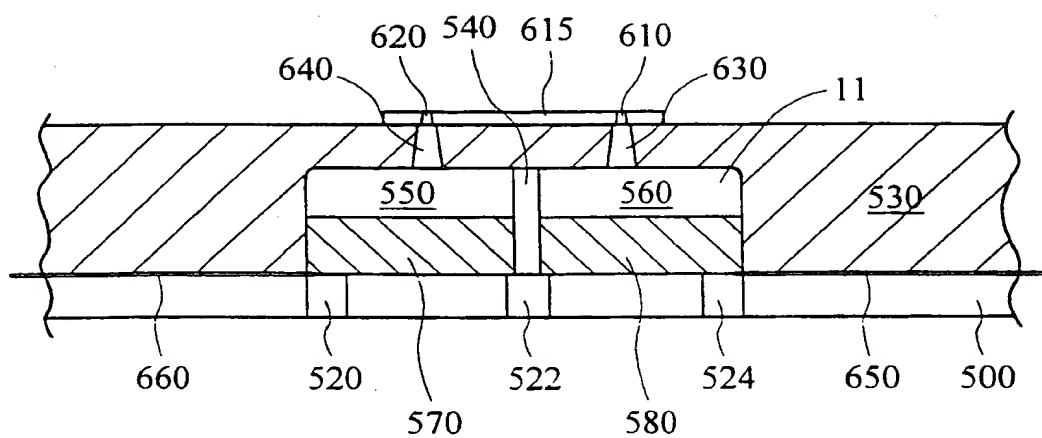


Fig. 6



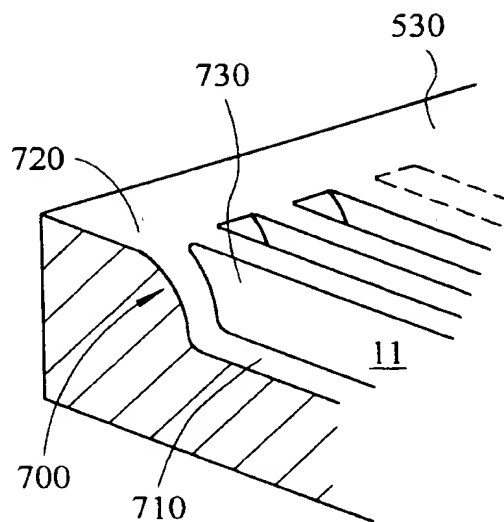
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Fig. 7



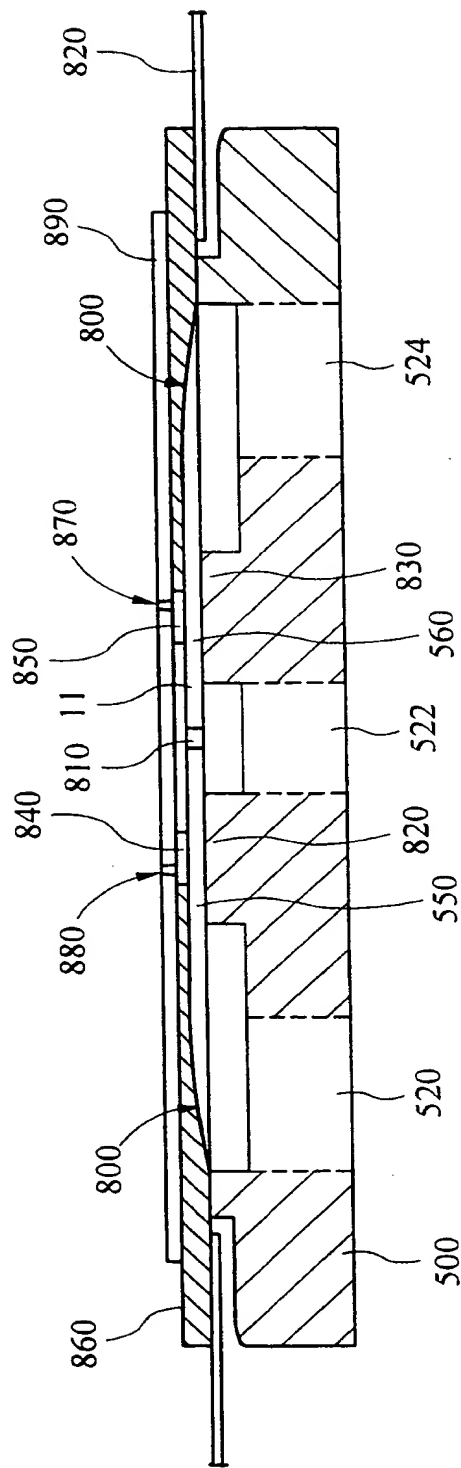
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Fig. 8



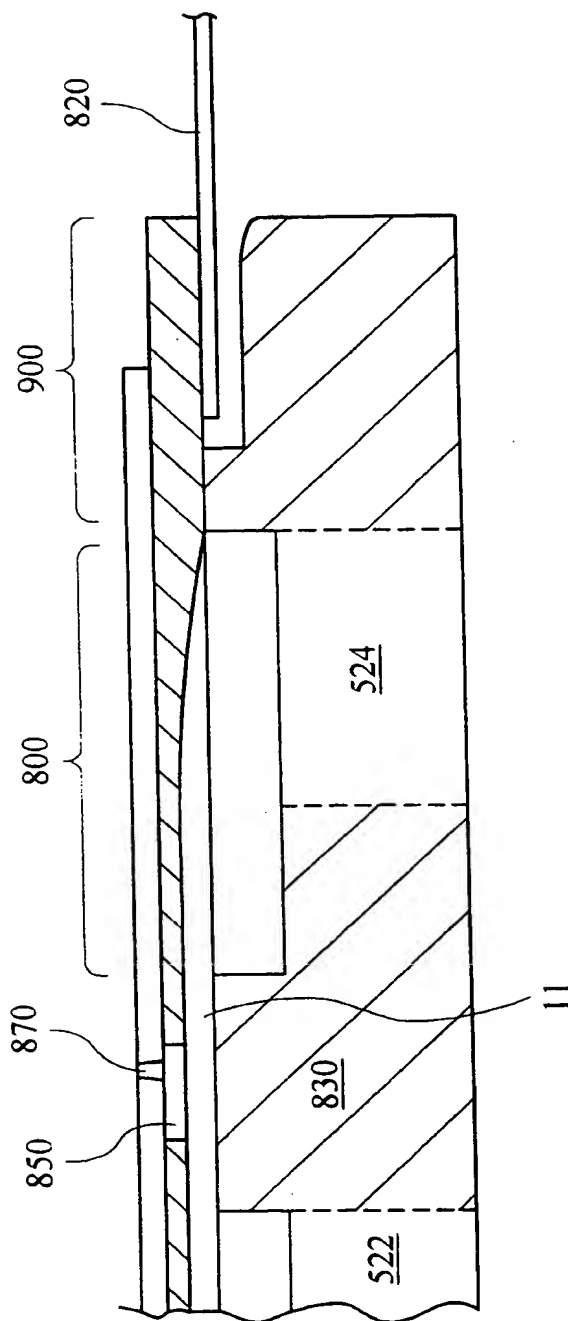
9/10

Fig. 9



10/10

Fig. 10



INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/03050

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B41J2/14 B41J2/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 364 136 A (AM INT) 18 April 1990 cited in the application see abstract; figures 1-8 ---	1, 19
A	GB 2 288 765 A (CITIZEN WATCH CO LTD) 1 November 1995 see abstract see page 2, paragraph 2-3; figure 3 ---	1, 19
A	WO 91 17051 A (XAAR LTD) 14 November 1991 cited in the application see abstract see page 7, paragraph 7 - page 8, paragraph 1; figure 10 --- -/-	1, 19

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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- "&" document member of the same patent family

Date of the actual completion of the international search

16 February 1999

Date of mailing of the international search report

03. 03. 1999

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Fax: (+31-70) 340-3016

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Nielsen, M

INTERNATIONAL SEARCH REPORT

Int. l. Application No

PCT/GB 98/03050

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>EP 0 723 869 A (SEIKO EPSON CORP) 31 July 1996 see abstract see column 5, line 21-33; figure 4B see column 12, line 48 - column 13, line 28; figure 17</p> <p style="text-align: center;">---</p>	1,19
A	<p>WO 95 25637 A (SPECTRA INC) 28 September 1995 see abstract; figures 1,5,6</p> <p style="text-align: center;">---</p>	1,19
A	<p>WO 92 10367 A (MARKPOINT DEV AB) 25 June 1992 see abstract see page 8, paragraph 6 - page 9, paragraph 1; figure 10</p> <p style="text-align: center;">---</p>	1,19
A	<p>US 4 611 219 A (SUGITANI HIROSHI ET AL) 9 September 1986 see column 6, line 30 - column 8, line 13; figures 9B,10B</p> <p style="text-align: center;">---</p>	11,24
A	<p>EP 0 655 334 A (SEIKO EPSON CORP) 31 May 1995 see abstract; figure 22A</p> <p style="text-align: center;">---</p>	11,24
A	<p>DE 39 17 434 A (SIEMENS AG) 9 November 1989 see abstract see column 4, line 3-16; figures 1-4,6</p> <p style="text-align: center;">---</p>	11,24
A	<p>EP 0 767 061 A (XEROX CORP) 9 April 1997 see abstract see column 11, line 5-8; claim 1</p> <p style="text-align: center;">---</p>	11,24
A	<p>DE 24 29 232 A (OLYMPIA WERKE AG) 8 January 1976 see figure 1</p> <p style="text-align: center;">-----</p>	11,24

INTERNATIONAL SEARCH REPORT

Inte. tional application No.
PCT/GB 98/03050

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
1-29
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-10,19-23

Droplet deposition apparatus according to claim 1 and method of its manufacture according to claim 19, the apparatus (print head) being of the shear-mode piezo-electric activated type having a cover, wherein the cover incorporates two ports for supply of droplet liquid, the ports being spaced along a channel on either side of a droplet ejection opening (nozzle).

2. Claims: 11-18,24-29

Droplet deposition apparatus according to claim 11 and method of its manufacture according to claim 24, the apparatus (print head) being of the shear-mode piezo-electric activated type having a cover, wherein a bottom longitudinal surface of a channel is formed with two openings (nozzles) for droplet ejection.

3. Claims: 30-58

Droplet deposition apparatus according to claim 30 and method of its manufacture according to claim 31, the apparatus (print head) being of the shear-mode electric signal (piezo-electric) activated type having a cover, wherein the point of electrical connection between a conductive track on the surface of the cover and an actuator means is lying outside a channel;

as well as

droplet deposition apparatus according to claim 57 and method of its manufacture according to claim 58, the apparatus (print head) being of the shear-mode piezo-electric activated type having a top sheet (cover), wherein sealing means is separating a forward part of a channel from a rearward part, the electrical connection lying in said rearward part (i.e. outside the channel).

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 98/03050

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 98/03050

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